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DEFINING THE FUTURE

Airworthiness Certification Strategy for Global Hawk HALE

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Agenda

- **Introduction to Global Hawk High Altitude Long Endurance (HALE) Platform**
 - Mission requirements and system overview
 - Flight operations summary
- **HALE Structural Design Overview**
 - Design drivers
 - Integrated structural test program
- **ASIP and Airworthiness Certification**
 - Tailored ASIP for HALE UAV's
 - Tailored ASIP for Global Hawk
- **Summary**

System Designed To Meet Challenging Mission Requirements

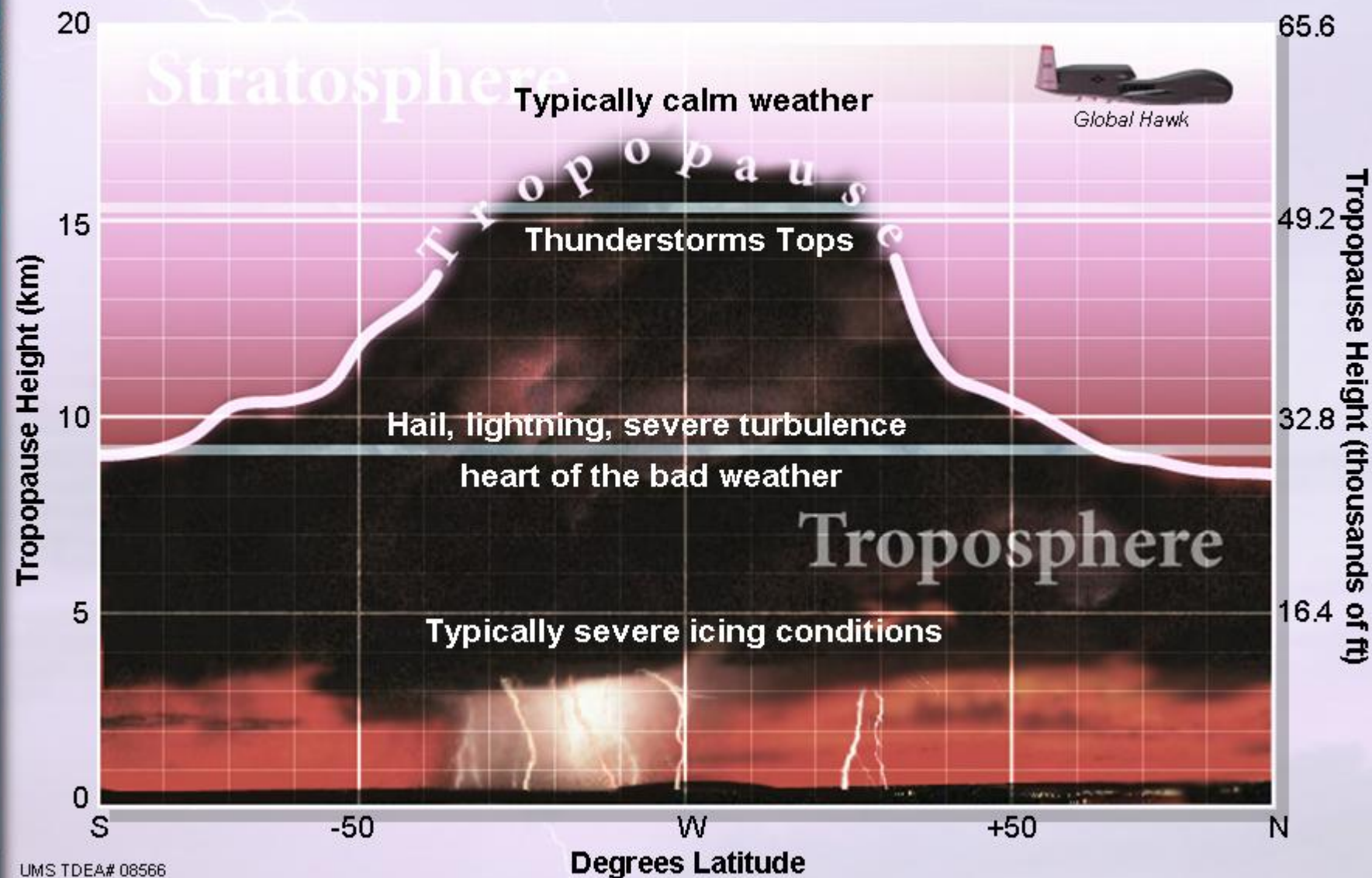
- Unmanned autonomous operation
- Automated in-flight contingencies
- Long endurance (30+ Hours)
- High altitude (60,000+ feet)
- 3,000 lbs Multi-Int payload capability
- Real-time mission control, override & re-tasking
- Airspace integration for worldwide operations
- Multi service interoperability
- Cost effective redundancy for autonomous flight operation

High Altitude, High Speed, Long Endurance

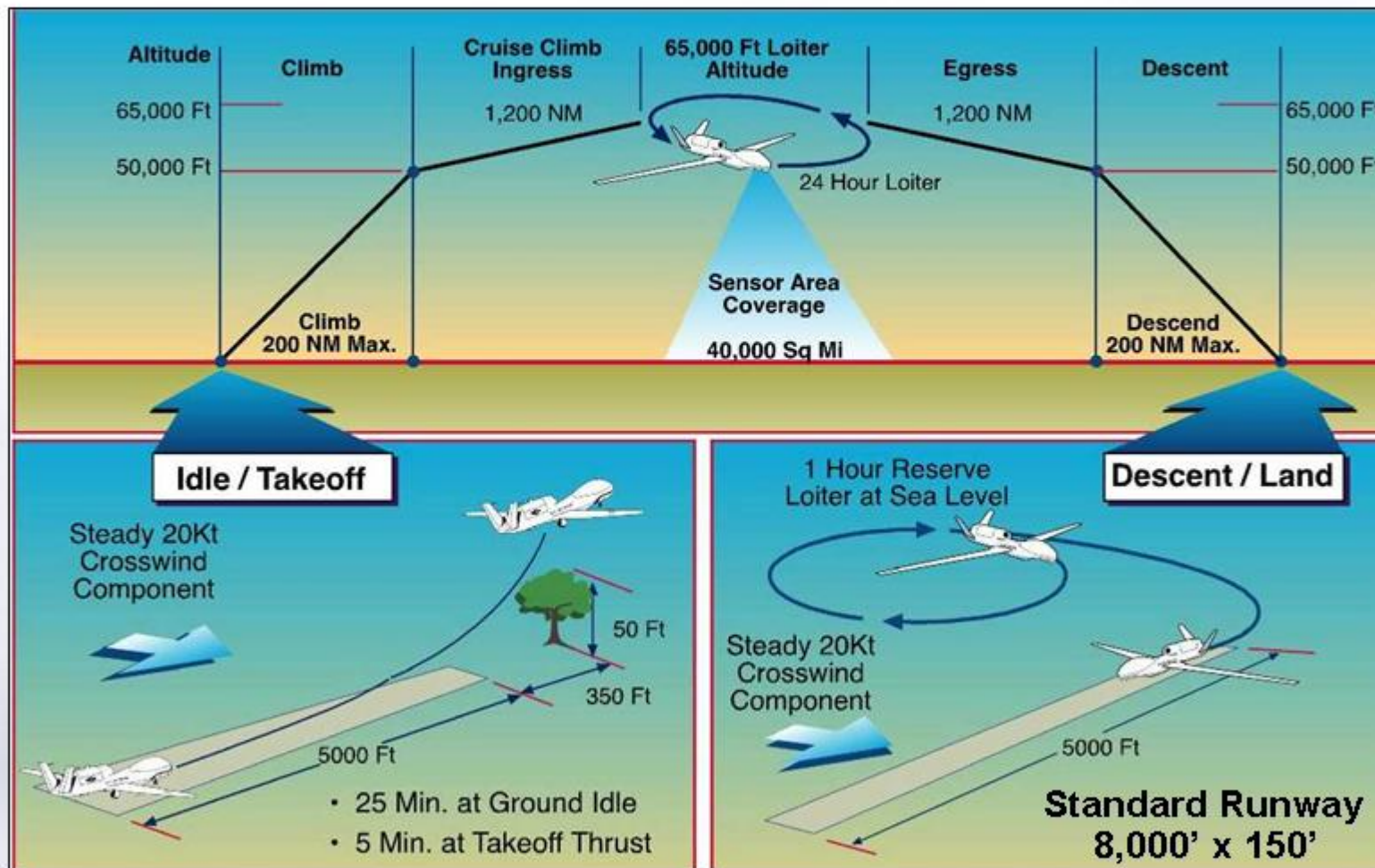
1. High altitude is critical for turbulent weather avoidance
2. True airspeed & therefore ground speed are maximum at high altitude
3. Winds are light & variable at high altitude
4. High altitude operations do not conflict with other air traffic
5. High altitude provides longer sensor range
6. Long endurance at high altitude provides maximum area surveillance capability

Generally, conditions become exponentially better at altitudes above 55K ft

High Altitude is Critical for Weather Avoidance



Typical Global Hawk Mission Profile



Automated In-Flight Contingencies

- **Contingency 1 - Loss of Command & Control**
 - **Pre-Determined Autonomous Navigation Until C2 is Re-established or, if not, to an Autonomous Landing at Home Base or Predetermined Contingency Base**
- **Contingency 2 - Loss or Malfunction of Critical Subsystem**
 - **Autonomous Return to Base or to a Predetermined Contingency Airfield**
- **Contingency 3 - Inoperative Engine**
 - **Glide to Home Base or a Pre-Determined Contingency Airfield; 45 Minutes of Electrical Power Available**
- **Contingency 4 - Automatic Take-Off Abort; Automatic Landing Abort**
 - **Both Aborts Triggered By Exceeding Safe Criteria for Respective Operation**

Historical Flight Operation



Flight Summary

Program Totals:

- ~900 flights / 14,000 hours
- 10,000 combat hours
- ~ 5,000 hrs on one vehicle
 - Tear down inspection with no major anomaly

Flight History

- Contract award May 1995
 - First flight (Block 10) Feb 28, 1998
 - First flight (Block 20) March 1, 2007
- Altitude – 60,000+ feet
- Duration – 30+ hours
- Operated In Jurisdiction of 14 Foreign Airspaces

Global Hawk Structural Design Review

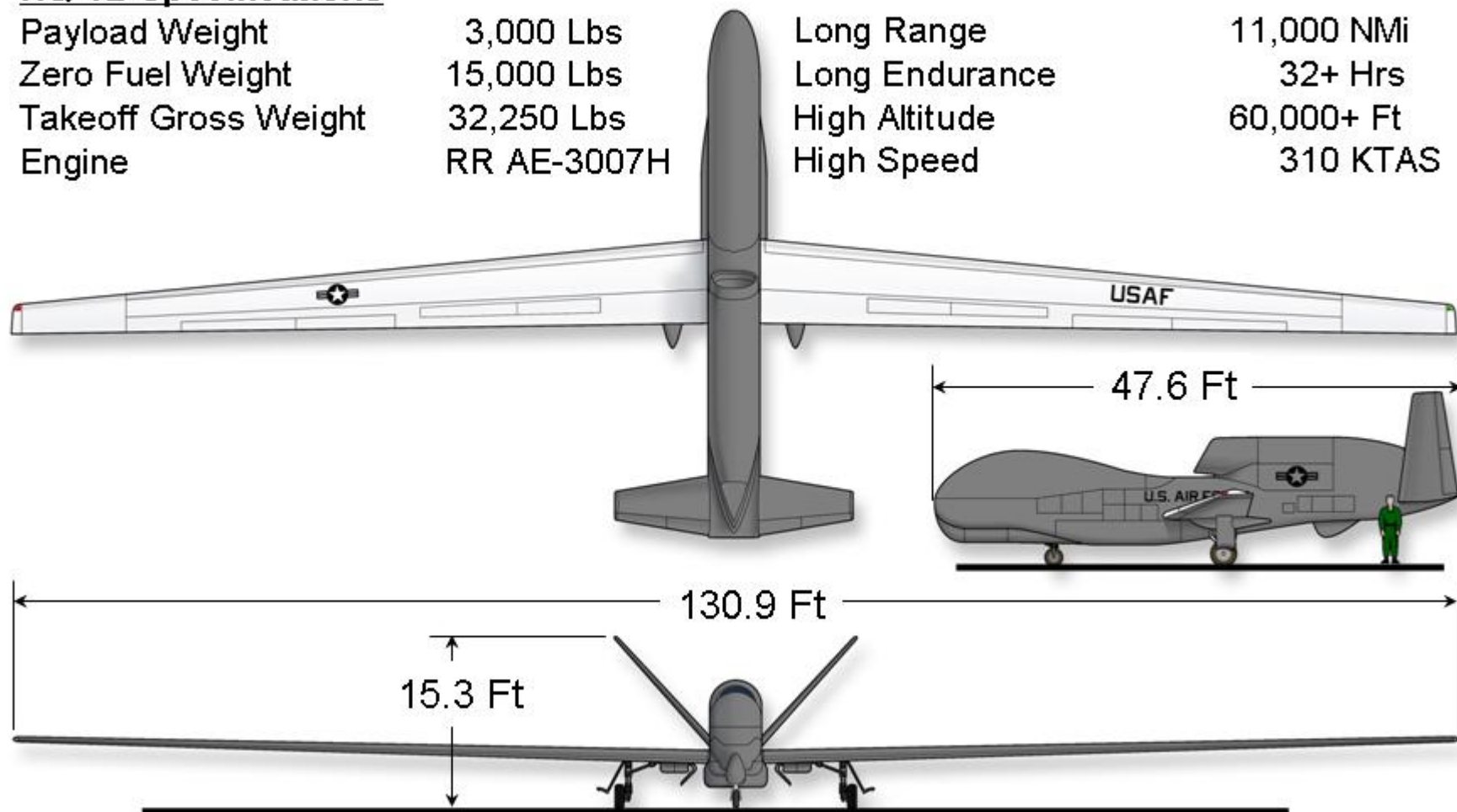
Systems Integration

Shipbuilding
Electronic Systems
Radar and Air Defense

Block 20 Configuration Specifications

RQ-4B Specifications

Payload Weight	3,000 Lbs	Long Range	11,000 NMi
Zero Fuel Weight	15,000 Lbs	Long Endurance	32+ Hrs
Takeoff Gross Weight	32,250 Lbs	High Altitude	60,000+ Ft
Engine	RR AE-3007H	High Speed	310 KTAS



Structural Design Overview

Fuselage Design

- Conventional Metallic Design
- Machined Al Bulkheads, Frames, Longerons
- Riveted Al Skins
- Bonded Metallic Sandwich Compartment Doors

Wing Design

- Wet Wing
- High Modulus GrEP Laminate skins
- GrEP Spars And Ribs
- Machined Ti Ribs At Critical Joints
- Cold Bonded Structure

V-Tail, Aft Fuselage, Nacelle, Radomes, Fairings Design

- GrEP and/or FG Sandwich Structures
- Nomex Honeycomb Core
- GrEP Laminate Spars, Frames Where Necessary
- Cold Bonded Structures
- Machined Al or Ti Fittings As Required

Bonded Structures Adhesive Selection

- R.T. cure epoxy adhesive (paste)
- Best system at reasonable cost, much lower in cost than film adhesive
- Good combination of pot life, handling time, and full cure capability at room temperature
- Qualified for exposure and use with water and JP fuels
- Evaluated for different bondline thickness
- Extensive use in industry and readily available
- Application on the international Space Station
- Extensive evaluation by AFRL

Bond Adhesive Requirements

- **Moisture and Temperature Exposure**
 - Require excellent hot/wet glass transition temperature
 - Cryogenic temperatures at high altitude
- **Chemical Exposure**
 - Need excellent adhesive solvent exposure properties
 - JP-8, JP-5 and hydraulic fluids
- **Typical Strength Properties Evaluated**
 - Design operating strains
 - Joints strain-to-failure
 - Lap shear and peel strength
 - Durability and damage tolerance
- **Major emphasize on adhesive bonding process control and stability**
 - Identify critical parameters
 - Quantify quality assurance
 - 100% NDI (Ultrasonic)

Primary Structural Design Drivers

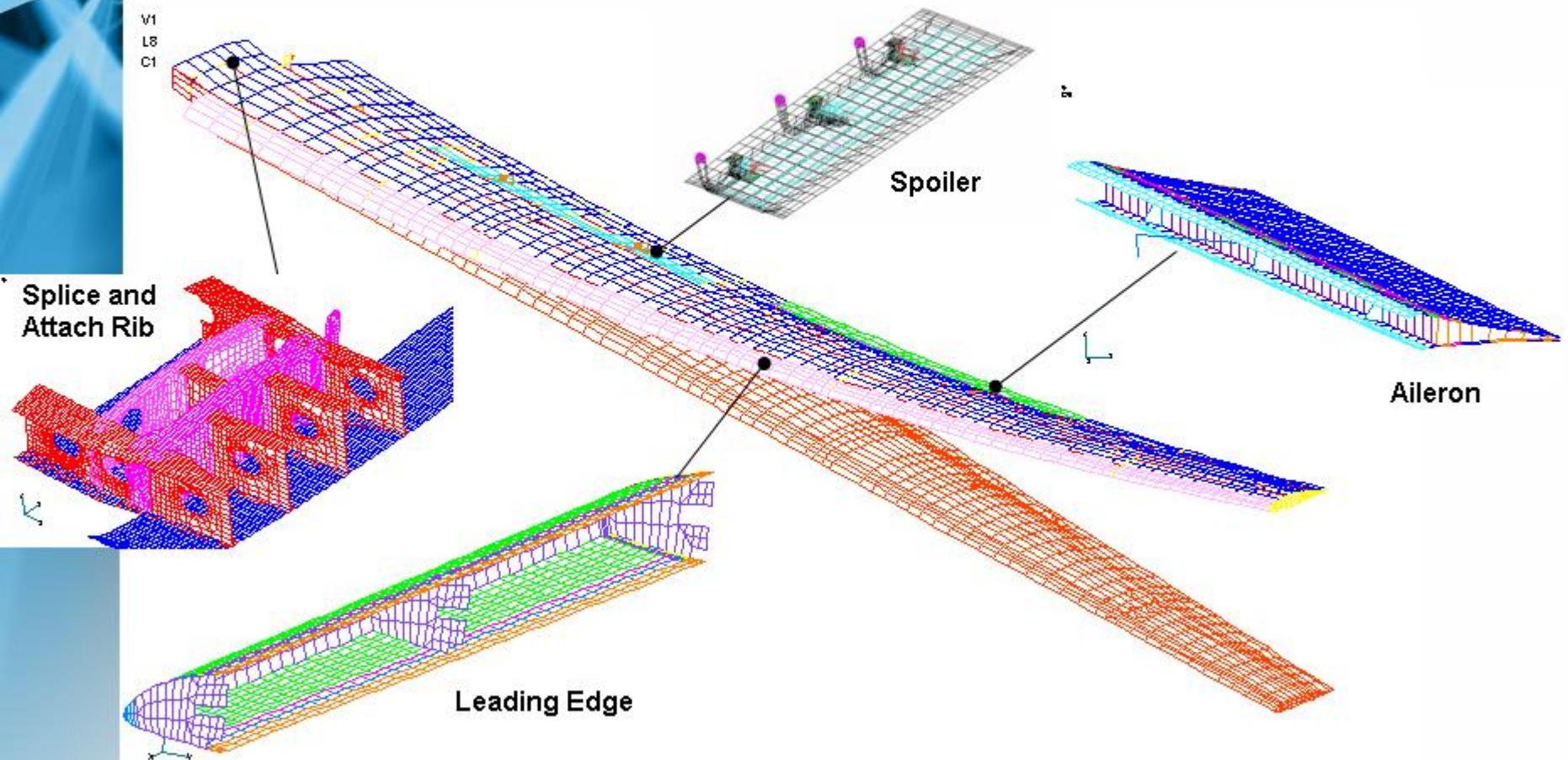
- **Maneuver Loads**
 - 1.5g typical cruise maneuver controlled by software
 - Worst pull-up maneuver < 3g max
- **Gust Loads (90% of mission spent above 50K = less probability of encountering high gust speeds)**
 - 3.2g gust load factor based on mission cycle analysis
- **Ground Operation Loads**
 - Controlled by software for low sink rate, and moderate taxi and braking
- **Airspeeds**
 - $V_{\text{cruise}} = \text{Mach } 0.6 \text{ at altitude}$
 - $V_{\text{nte}} = 165 \text{ KEAS}$

Bottom Line – Benign and Predictable Loads Envelope

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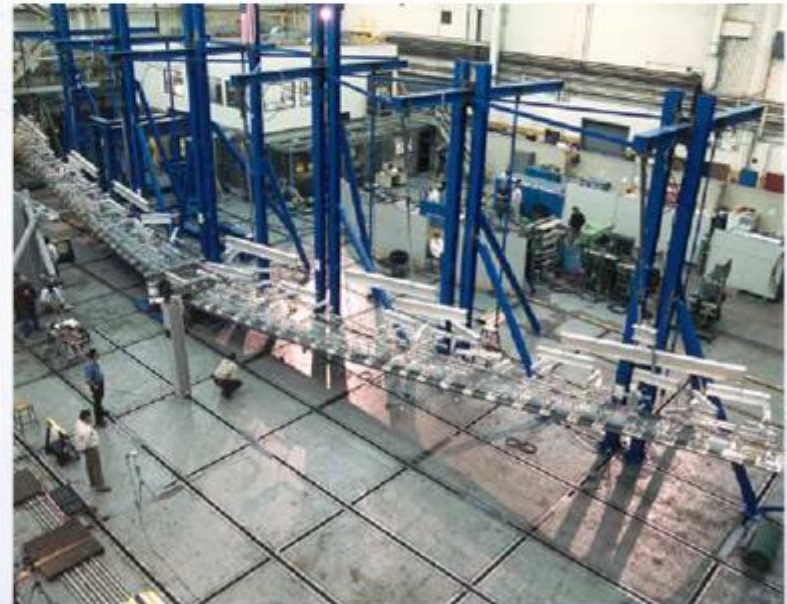
Finite Element Models

- Validated wing FE model with excellent correlation to test results
 - Manufacturing article test, proof test, GVT, and ultimate testing



Global Hawk ASIP Integrated Structural Test Program

- Implement tailored ASIP requirements with an integrated structural test program towards airworthiness certification of Global Hawk
- Building block approach
 - Coupon test
 - Joint allowables
 - Element test
 - Component level tests
 - Proof tests
 - Full-scale static tests
 - Component level durability tests
 - "Full-scale" durability test



Structures – Testing and Results

Static Load Testing Overview

- **Component/Coupon Testing**
 - Material Allowables Program
 - Coupon Testing Including Damage
 - Adhesive Strength
 - Manufacturing Study Article (MSA #1) Test
 - 10' Cantilevered Wing Section Tested To Failure
 - V-Tail Main Spar
 - 5' Section Including Attachment Tested to 200% Limit
 - BL 0 Wing Splice Element Test
- **Proof Testing – All Composite Primary Structure**
 - Wing, Aft Fuse, V-Tails to 100% Limit Load
- **Limit and Ultimate Loads Testing**
 - All Critical Flight And Ground Loads
 - Wing Test
 - MLG
 - Fuselage Tests
 - NLG
 - V-tail
 - Composite AFT fuselage

Structures – Testing and Results

Durability and Damage Tolerant Testing Overview

- **Component/Coupon Testing**
 - Material Allowables Program
 - Cyclic Testing Including un-bond, and delamination
 - Manufacturing Study Article (MSA #2) Test
 - Effect of defect assessment for known defects
 - V-Tail Main Spar
 - Effect of defect for impact damage and excess porosity
 - BL 0 Wing Splice Element Test
 - Passed durability tests, impact damage study
- **“Full” Scale Durability Testing**
 - V-Tails
 - Composite aft fuselage
 - Fracture critical fittings

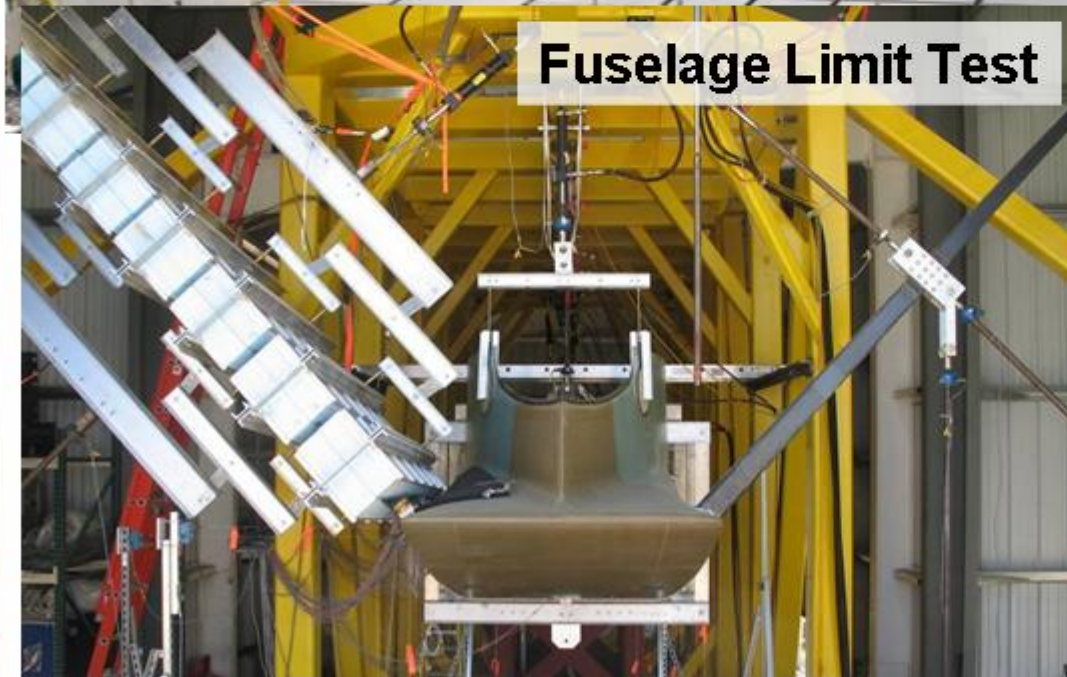
Structures – Testing and Results

Static Load Tests

Wing Test To Failure



Fuselage Limit Test



BL 0 Splice Test

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Structures – Testing and Results

Dynamic And Flight Testing Overview

- **Dynamic Tests**
 - **Ground Vibration Modal Testing (GVMT)**
 - Measures Natural Modes, Frequencies, Damping
 - Full And Zero Fuel
 - Soft Support System To Simulate Free Flight
 - **Control Surface Stiffness And Freeplay Tests**
 - **Test Data Is Used For Analysis**
 - Flutter And Modal Analyses Updates
 - Flexible Correction To Rigid Aero Database
 - Results To G&C For Software Notch Filters
- **Flight Testing**
 - Taxi – Gear Loads And Vibrations Monitored

Structures – Testing and Results

Development Tests

Manufacturing Study Article Test



Wing Section



GVMT Soft Supports



Shakers

GVMT

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Structural Static Proof Tests

- Successfully completed all static proof tests to date
 - Wings: AF-8 through AF-15
 - Aft Fuselage: AF-8 through AF-16
 - V-tails: AF-8 through AF-15



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Wing Ultimate Test

- **100% Of Conditions Complete**
 - No anomalies encountered
 - Ultimate testing of fuel pressure and control surfaces completed
 - All limit load test completed
 - Maneuver, up-gust, down bending gust and landing gear loads
 - Ultimate strength margin testing complete Sept.07
 - Maximum up bending condition tested to failure
 - Predicted failure at 131%, failed at 132% DLL



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ULT Wing – Limit Taxi Down Bending



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Fuselage Ultimate Test

- No anomalies encountered
 - Designed to F.S. 1.25
 - No buckling at ultimate
 - Passed F.S. 1.5



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HALE ASIP and Airworthiness Certification

Tailored ASIP for HALE UAV's

- **Global Hawk is Trial Case for HALE ASIP Tailoring**
 - Use JSSG 2006 and MIL-STD-1530 guidelines
 - Rapid pace spiral development requires alternative approaches
 - Building block approach reduces acceptable risk
 - Evaluate delay of full-scale testing when acceptable alternate methods are employed
- **ASIP tailoring decisions for HALE UAV's must consider acquisition and life cycle costs along with the quantification of increased risk**

Tailored ASIP for Global Hawk HALE

- **Mission Specific Tailoring**
 - HALE vs Combat = speed and maneuver loads requirements
 - High altitude vs low altitude = gust loads exposure
 - Short mission vs long endurance = GAG cycles
- **Global Hawk Approach**
 - HALE mission minimizes maneuver requirements
 - Pre-programmed autonomous maneuvers within flight envelope
 - High altitude operations minimize exposure to gusts
 - Long endurance flights minimize structural cycling

Tailored Testing

- Mission requirements allow consideration of slight risk increase due to delay of full-scale testing
- Benefits
 - Supports fast paced spiral development strategy
 - Minimizes initial acquisition costs
 - Provides Warfighter with needed capability sooner
- Implications on EMD
 - Added costs on production due to proof testing
- Implications on Life Cycle
 - System support increased due to additional inspections

Tailored ASIP for HALE UAV's - examples

- **Tailoring Examples – Potential Safety Impact**
 - Truncated EMD stage – Early LRIP go-ahead
 - Reduced Factor of Safety for gust events
 - Typical gust load criteria based on high altitude consistent mission usage, and time at altitude
 - Reduced impact damage resistance for light-weight composite structure design

Summary

- **Typical ASIP requirements and elements of airworthiness certification can be tailored for HALE UAV's**
 - Low mission GAG cycles
 - Repeatable and controlled missions
- **Global Hawk has successfully demonstrated operational airworthiness within acceptable risk**
 - ~ 900 missions and 14,000 flight hours
- **Tailored HALE ASIP tasks may increase life cycle cost**
 - Technical risk must be balanced with economical impact

Questions?



Airworthiness Certification Strategy for Global Hawk HALE

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This paper was received as a PowerPoint presentation without supporting text.

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